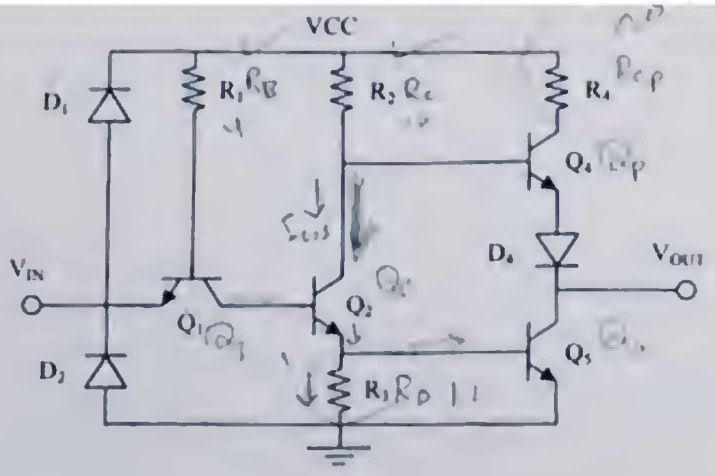
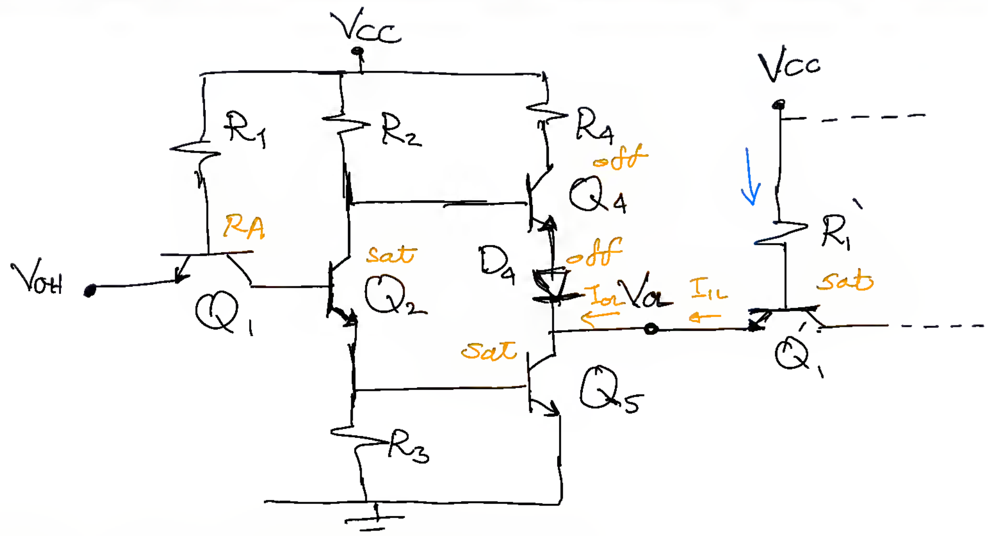


Question 2: [7 Marks]

For the standard TTL inverter shown in question 1, give values for all the resistors if:

$V_{OL} = 0.2V, V_{IL} = 0.5V, V_{IB} = 1.2V, V_{OB} = 6.6V, V_{IH} = 1.4V, V_{OH} = 8.6V, P(OH) = 10mW, \text{and } P(OL) = 35.8mW$



$$V_{OH} = V_{CC} - V_{BE}(FA) - V_D(ON)$$

$$V_{CC} = V_{OH} + V_{BE}(FA) + V_D(ON) = 8.6 + 2(0.7) = 10V$$

$$\boxed{V_{CC} = 10V}$$

$$V_{OL} = V_{CE}(sat) = 0.2V \implies \boxed{V_{CE}(sat) = 0.2V}$$

$$V_{IL} = V_{BE}(FA) - V_{CE}(sat)$$

$$V_{BE}(FA) = V_{IL} + V_{CE}(sat) = 0.5 + 0.2 = 0.7V$$

$$\boxed{V_{BE}(FA) = 0.7V}$$

$$V_{IH} = 2V_{BE}(sat) - V_{CE}(sat)$$

$$V_{BE}(sat) = \frac{V_{IH} + V_{CE}(sat)}{2} = \frac{1.4 + 0.2}{2} = 0.8V$$

$$\boxed{V_{BE}(sat) = 0.8V}$$

$$P(OH) = I_{cc}(OH) \times V_{cc} = I_{R_1}(OH) \times V_{cc}$$

$$I_{R_1}(OH) = \frac{P(OH)}{V_{cc}} = \frac{10mW}{10} = 1mA$$

$$I_{R_1}(OH) = \frac{V_{cc} - V_{BE}(sat) - V_{CE}(sat)}{R_1}$$

$$R_1 = \frac{5 - 0.8 - 0.2}{1m} = 4k\Omega \Rightarrow \boxed{R_1 = 4k\Omega}$$

Assume $\beta_F >> 1$, negelect I_B's

$$I_{R2}(OL) = I_{C,2} = I_{E,2} = I_{R3}$$

$$V_{OB} = V_{cc} - I_{R2}(OL) R_2 - V_{BE}(FA) - V_D(ON)$$

but $I_{R3} = \dfrac{V_{BE}(FA)}{R_3}$

$$V_{OB} = V_{cc} - \frac{R_2}{R_3} V_{BE}(FA) - V_{BE}(FA) - V_D(ON)$$

$$\frac{R_2}{R_3} = \frac{V_{cc} - V_{OB} - V_{BE}(FA) - V_D(ON)}{V_{BE}(FA)} = \frac{10 - 6.6 - 0.7 - 0.7}{0.7}$$

$$\frac{R_2}{R_3} = 2.857 \Rightarrow R_2 = 2.857 R_3$$

$$I_{R_1}(OL) = \frac{V_{cc} - V_{BC}(RA) - 2V_{BE}(sat)}{R_1} = \frac{10 - 0.7 - 2(0.8)}{4K}$$

$$I_{R_1}(OL) = 1.925mA$$

$$P(OL) = [I_{R1}(OL) + I_{R_2}(OL)] V_{cc}$$

$$I_{R1}(OL) + I_{R_2}(OL) = 3.58mA$$

$$I_{R2}(oL) = 3.58m - 1.925m = 1.655mA$$

$$I_{R3} = \frac{V_{BE(sat)}}{R_3}$$

$$R_3 = \frac{V_{BE(sat)}}{I_{R3}} = \frac{0.8}{1.655m} = 0.483k\Omega$$

$$\boxed{R_3 = 0.483k\Omega}$$

$$R_2 = 2.857R_3 = 2.857 \times 0.483k = 1.38k\Omega$$

$$\boxed{R_2 = 1.38k\Omega}$$

since R_4 is typically the tenth of R_2

$$R_4 = \frac{R_2}{10} = \frac{1.38k\Omega}{10}$$

$$\boxed{R_4 = 138\Omega}$$

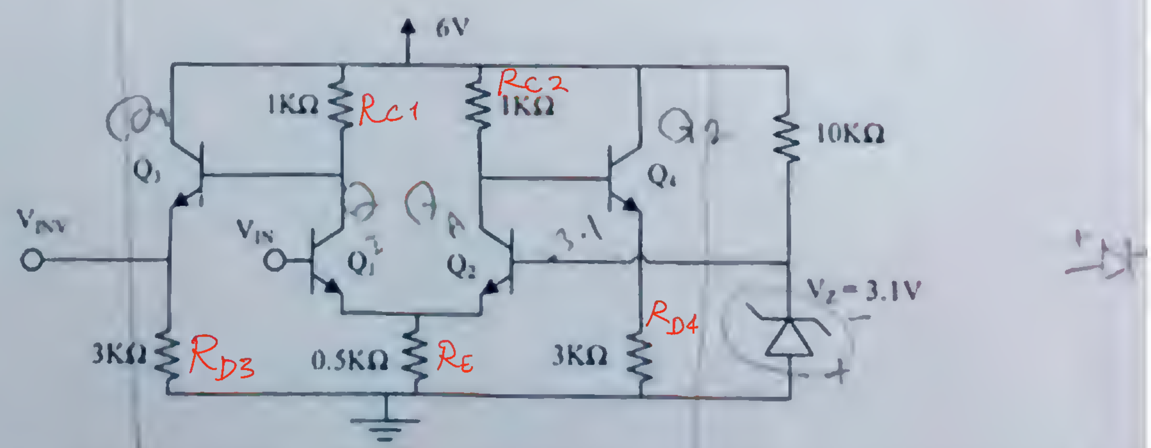
$R_1 = 4k\Omega$	$R_2 = 1.38k\Omega$
$R_3 = 0.483k\Omega$	$R_4 = 138\Omega$

Question 3: [6 Marks]

For the ECL inverter shown in the following figure. Assume $\beta_F = 50$ and $V_{BE}(ECL) = 0.75V$.

a) Sketch the VTC. Please calculate and label all voltages including V_S
b) Determine the maximum fan-out of the inverter. Assume that the load gates have reduced V_{OH} of the driving gate by 25mV.
c) Calculate the average power dissipation of the inverter.

$N = I_{OH}/I_{IN}$



$V_{BB} = V_E = 3.1V$

V_{OH}:

for $V_{in} < V_E$ Q_1 is off

$$V_{OH} = V_{CC} - I_{B3}R_{C1} - V_{BE3}(ECL) = 6 - I_{B3} \times 1K - 0.75$$

$$V_{CC} - I_{B3}R_{C1} - V_{BE3}(ECL) - I_{E3}R_{D3} = 0$$

But $I_E = (1+\beta_f) I_B$

$$V_{CC} - I_{B3}R_{C1} - V_{BE3}(ECL) - (1+\beta_f)I_{B3}R_{D3} = 0$$

$$I_{B,3} = \frac{V_{CC} - V_{BE3}(ECL)}{R_{C1} + (1+\beta_f)R_{D3}} = \frac{6 - 0.75}{1K + (1+50)3K} = 34.1 \mu A$$

$$V_{OH} = 6 - 0.0341m \times 1K - 0.75 = 5.22V$$

$$\boxed{V_{OH} = 5.22V}$$

V_{IL} & V_{IH}:

$$V_{IL} = V_{BB} - 0.05 = 3.1 - 0.05 = 3.05V$$

$$V_{IH} = V_{BB} + 0.05 = 3.1 + 0.05 = 3.15V$$

$$\boxed{V_{IL} = 3.05V} \qquad \boxed{V_{IH} = 3.15V}$$

V_{OL}: for $V_{IN} > V_E$ Q_1 is FA

$$V_{OL} = V_{CC} - I_{C1}R_{C1} - V_{BE3}(ECL) = 6 - I_{C1} \times 1K - 0.75$$

$$I_{C1} \approx I_{E1} = \frac{V_{IN} - V_{BE1}(ECL)}{R_E}$$, but $V_{IN} = V_{IH}$

$$= \frac{3.15 - 0.75}{0.5K} = 4.8mA$$

$$V_{OL} = 6 - 4.8m \times 1K - 0.75 = 0.45V$$

$$\boxed{V_{OL} = 0.45V}$$

V_S:

when V_{IN} increases beyond V_{IH} Q_I saturate @ $V_{IN} = V_S$

$$I_{C1} \simeq I_{E1} = \frac{V_{IN} - V_{BE1}(sat)}{R_E}$$

$$V_{INV} = V_{CC} - I_{C1}R_{C1} - V_{BE3}(ECL) \quad \text{—— } ①$$

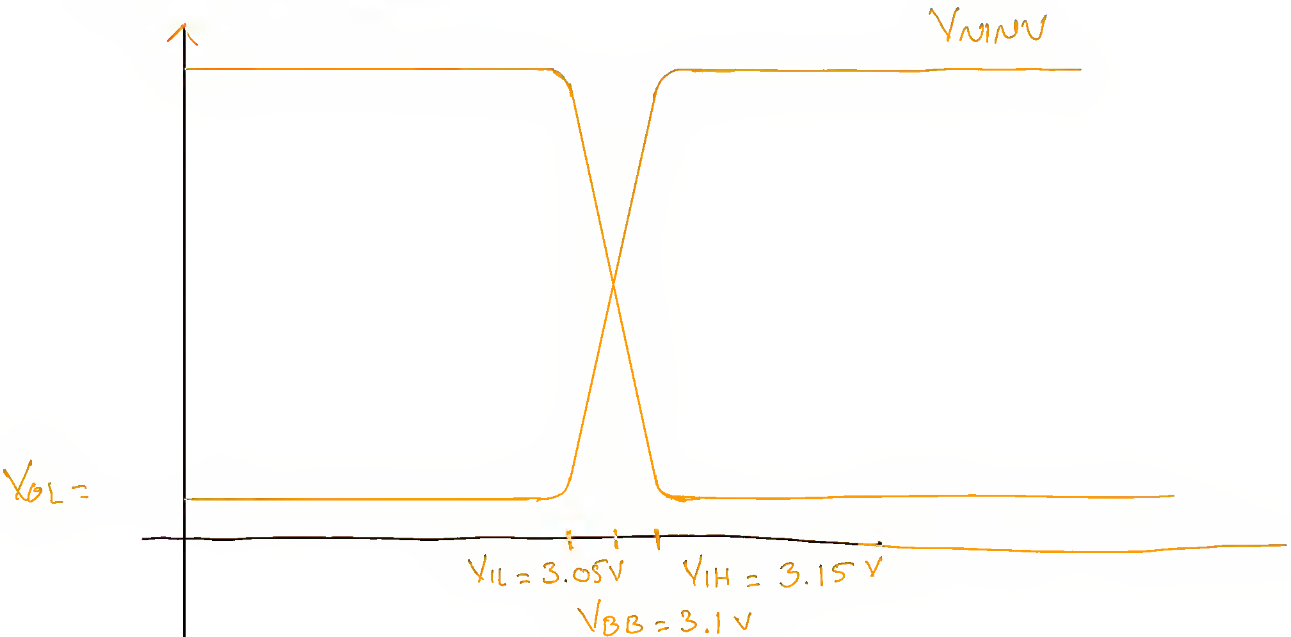
$$V_{INV} = V_{IN} - V_{BC1}(sat) - V_{BE3}(ECL) \quad \text{—— } ②$$

solve ① & ② for $(V_{IN} = V_S)$

$$V_S = \frac{V_{CC} + \frac{R_{C1}}{R_E} V_{BE1}(sat) + V_{BC1}(sat)}{1 + \frac{R_{C1}}{R_E}}$$

$$= \frac{6 + \left(\frac{1K}{0.5K}\right)(0.8) + 0.6}{1 + \frac{1K}{0.5K}} = \frac{6 + 2 \times 0.8 + 0.6}{1 + 2} = 2.73\,V$$

$$\boxed{V_S = 2.73\,V}$$



قيمة V_S غير منطقية و يفترض ان $V_S > V_{IH}$